3 July 1967

Professor H. Orin Halvorson
Department of Biochemistry
College of Biological Sciences
St. Paul, Minnesota 55101

Dear Professor Halvorson:

My understanding of the way in which the material on injuries and environmental stresses is being handled is that the section c which I prepared and which is now entitled "Man, Machines and Environmental Stresses" will replace both section c and section d of the second draft so that it combines the material that Dr. Aldrich and I had prepared individually. I am enclosing a fresh copy in a form which may be used directly. I have also managed to get together a very short section on Marine Biology and National Defense which I hope will be sufficient to call attention to a very important but not well publicized area of activity. Just where it should be placed in the report I do not know, but it might very well become section d and follow the Man, Machines, etc., section.

Copies of this are being sent to all the members of the Committee and I hope they will be able to find time to criticize it. I am sorry for the delay but I have been very much tied up with last minute work associated with my retirement. In case you need to reach me, I will be here at NMRI through the middle of this month and for the last two weeks of July, I can be reached c/o the Physiological Department of the Woman's Medical College, Philadelphia, 19129. I shall be away for most of August but will become a regular staff member at the Woman's Medical College after Labor Day.

Sincerely yours,

D. E. GOLDMAN
Captain, MSC, USN. (Ret.)

Encls:
(1) Subject material

Copy to:

STAT [redacted]
Dr. Ira Baldwin
Dr. John Dingle
Dr. Riley Housewright
Dr. Herbert Pahl

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MARINE BIOLOGY AND NATIONAL DEFENSE

The tremendous role played by the Navy in national defense makes it imperative to understand the Navy's environment, i.e., the sea. Oceanology, as it is now called, includes not only the study of the physical characteristics of the marine environment but to an equal degree, an understanding of its biological aspects. Marine organisms, from plankton to whales, exert many important effects.. For example, they can interfere with underwater communications, drastically reduce the lifetime and effectiveness of equipment and produce hazards to people in the water.

Objects of any material, natural or artificial, submerged in the sea attract biological organisms in a remarkably short time. Although it is not proven, it is likely that the first settlers consist of bacteria and other minute forms which attach and form a slime on the material. Such a slime may be essential to the settling of other organisms. In any case fouling begins almost immediately after material is submerged in the water. The time before fouling is initiated, and the rate at which it accumulates depends on both seasonal and geographic factors. Ship's fouling is no longer as serious a problem as it once was partly because of the speed at which most ships are underway and partly because of the availability of protective coatings. The problem however is far from solved because other equipment is not so easily protected. Sonar domes, for example, cannot be painted and become inoperative with even small amounts of fouling. The struts of hydrofoil boats are equally susceptible to even minute amounts of fouling.

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Conduits, especially fire conduits, frequently foul while a vessel is in port and this fouling may be undiscovered until an emergency occurs at sea, and water is needed. While the biological organisms clogging the ducts can easily be killed with live steam and other chemical flushing, this does not solve the situation because the animals in many cases remain attached whether alive or dead. Persistent protective maintenance therefore is required. The cost incurred in dollars, time, and loss of efficiency in operation amounts to billions of dollars annually.

In addition to fouling, a good deal of destruction is caused by biological organisms which bore into wood, concrete and other construction materials. Again as in the case of the conduits, one of the major problems is the kind of boring which cannot be easily detected. Thus pilings may appear sound from a superficial examination of the exterior while the interior is completely riddled by the tubes of the borers. This is because the entrance into the wood is made by the larval form which is nearly microscopic. While much money has been invested in the development of good creosotes and methods for good creosote penetration, there is evidence that some creosotes are not effective against certain species of borers and other materials may be required to prevent this invasion.

Deterioration and general damage by biological organisms and their activities are not limited to fouling and boring however. Many

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animals are attracted in a remarkably short time to artifacts placed in the water. If these are to be kept from too easy observation, they may be camouflaged or otherwise protected. The protection may be overlaid or destroyed however by visiting animals. Contrariwise objects that are meant to be observed may be hidden by the camouflage of the fouling. In addition to biologically produced visual changes, animals such as fishes which may be attracted to equipment in the water are frequently noise producers and can serve as clues to the presence of artifacts because of the concentrated population of animals producing sounds. Behavior patterns are also useful as clues giving away the presence of submerged materials. Octopods for example are known to burrow under equipment lying on the bottom and to mark the area around their "caves" with shells of their prey. A circle of white shells surrounding a dark object on the bottom marks it off quite clearly.

Larger marine forms must also be dealt with. For example, research on sharks is important for a variety of reasons. There is a continuing need for development of better means for protecting personnel from predaceous shark activity. It should be noted that shark repellents and/or deterrents are needed not only for reasons of survival at sea, but also as means for alleviation of the problem of interference by sharks in naval operations incident to hydrographic, hydrobiological, and even space research. Damage to cables, flotation gear, and re-entry packages associated with the recovery of space equipment at sea has been attributed to strikes by sharks. Harassment of swimmers, divers, and boat crews continues to result in interference with work-boat operations, the servicing of underwater equipment, undersea research, salvage, UDT operations, and recreational swimming. The need for effectively protecting men of the operating forces from shark attack was tragically demonstrated early in World War II and led to the hurried development of a shark repellent packet for use by survivors of sea disasters. Carefully controlled tests of this material in recent years by methods not available at the time of its development indicate that this packet, still issued as Navy Standard Shark Repellent, would probably not be effective at an acceptable level over the wide range of conditions encountered in present day global operations of the Navy.

Less apparent, yet very important in terms of a direct relationship to naval operations, is the need to understand the mechanisms by means of which sharks are able at relatively great distance to sense the presence of prey and to navigate in its direction with a high degree of accuracy. In so doing, the shark is able to collect and evaluate a variety of environmental information in the form of chemical and physical stimuli under conditions of low signal noise ratio. The sense organs possessed by sharks for this purpose are yet to be fully identified, and even for those known to be present, the exact purposes and mechanisms of action are not at all well understood. It is clear that the shark possesses the ability to detect minute pertubations, and perhaps even potential gradients, in the water in such a manner to provide analysis of significance and directional information to the shark under conditions of relatively high background noise. When these systems are understood better, the geometrical patterns in which great numbers of sense organs are found on and just beneath the skins of sharks may be of great significance to those concerned with the development of submarine detection systems, underwater communications, and perhaps advanced fishing methods as well. Furthermore sharks have recently become quite important as "laboratory animals" in programs of study on biological processes related to normal and abnormal physiology and biochemistry.

The problem of interference with underwater communications has already been mentioned. It should be added since many marine organisms emit sounds, it is important to understand the identification of these sounds and to understand the circumstances and locations in which they are found. The marine biological problems in the above context involve ecological, physiological and behavioral factors as well as their interaction with geographic, seasonal and other considerations. While research, both basic and applied, has been carried out in these areas for a number of years, there are still many important problems which are far from solved and increased emphasis could well be placed in this area. The benefits to be derived are, of course, much broader than those of defense alone.

The research required to deal with these problems is considerably less expensive to the defense program than the losses in time, money and effectiveness.

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c) Men, machines and environmental stresses.

Man is still in the process of learning to live with machines. Whether his rate of learning is keeping up with the rate at which machines develop is perhaps questionable. In any case, he must try his best lest the machines overwhelm him. Furthermore, modern transportation exposes people not only to close contact with machines, but subjects them to an ever increasing variety of environmental conditions at a more rapid pace than ever before. One day a man may be in a temperate climate living a routine life and the next he may be in a hot, humid climate working, say, with jet aircraft or he may find himself in the artificial and perilous position of a crew member of a deep submergence vehicle in the ocean.

History and statistics suggest that while death and disability from disease are gradually being brought under control in military situations, it is doubtful if the same is true for injury and disability related directly to high-energy machines and unusual environments. Certainly any device generating large concentrations of power is a definite hazard. A list of such devices would be very long and would certainly include internal combustion engines, jet engines, atomic devices and electromagnetic and acoustic power generators. Vehicles containing some of these may also provide a complex interaction of several such sources, for example railroad trains, aircraft, trucks, tanks, ships, submarines and spacecraft. Along with physical

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forces generated by high-energy devices, there may be exotic substances, some toxic, as well as sharp changes in ambient pressure, temperature and humidity. While all of these problems are important to society in general, they are particularly important to the Armed Forces because of the much more intensive use made of these high-energy devices and the much higher costs and risks associated with them and their operation. The design and construction of machines and vehicles must take into account the physiological tolerance limits of their operators and of maintenance people with regard to the environmental forces. This involves a rather detailed knowledge of many aspects of human biology. In addition, the behavioral and social sciences become heavily involved when one includes the problems of effective use of these machines, particularly under the conditions of stress. For example, modern high-speed aircraft not only expose men to low ambient pressure, cold, intense noise and vibration, and even radiation, but the complexity of operating these aircraft makes great demands on behavioral capacity.

Considerable effort has been spent and progress made in extending the "motor function" of the military unit. To lesser extent, there has been an effort to increase man's sensory input through advanced engineering models which permit him to see and hear remotely. There is some reason to believe that a more careful anatomical-biophysical representation of the actual sensory systems which occur in nature might provide the blue-print for more advanced weapons systems of the future. The importance of developments in this area can hardly be underestimated when one considers the decision making which is required in the defense posture of modern military forces. Important as decision making may be in determining strategic or tactical operations, the success or failure depends to a considerable extent on the validity and timeliness of the information presented to the decision maker. Biology should be vitally concerned with this process as well as other disciplines related to the Life Sciences.

The problems of application of biological knowledge to defense problems are exceedingly complex. For example, the preparation of vehicles, weapons systems and procedures for their use often requires elaborate considerations of cost and time on the one hand and relative effectiveness and risk on the other. This type of analysis is particularly difficult to apply in situations where key information, in this case relating to biology, is missing. Research problems are not necessarily solved on schedule and important unpredicted results are sometimes obtained. Furthermore, while fruitful applications of research may take years to develop in the physical science, they may take a great deal longer in the biomedical areas, if only because the situation is so much more complex.

Necessary biological information is obtained not only from the current state of knowledge, but also from special studies directed toward particular situations as they develop. Progress in the accumulation of biological knowledge in general is more or less continuous but spurts of applied research are undertaken in response to immediate problems. Even in applied research however, the time required to obtain information of direct value and to apply it may be very long. This is particularly true since basic research results are not necessarily obtained in useful form and much applied research may then be needed to provide relevant numerical information for specific situations.

It should thus be clear that the application of biology to problems of national defense requires a strong research capability. Such a capability must extend well into basic research areas on the one hand and into applied studies on the other. Of course it is understood that we are referring here particularly to the areas involving the physiology, biochemistry, etc. of human beings. However, the problem is, of course, much broader, extending as it does into such areas as disease susceptibility or psychological stress. Considerable effort has been spent in studying performance activities of operators of highly complex machines. Beyond the purely behavioral aspects of this, there is good reason to believe that careful studies of sensory mechanisms would provide an important contribution not only for current systems but for the more advanced systems which the future will surely bring. A thoroughly adequate research program includes not only suitable facilities of which there appear to be many, but also a sufficient number of skilled scientists of which there are perhaps not a sufficient number. Beyond this, there is a great need for effective communication between the biologists who provide the information and the engineers and operations people who consume it. This problem of communication is a serious one partly because of the widely different backgrounds and attitudes of the two groups and partly because of the problem of physical location, since the scientist tends to stick to the laboratory, the design engineer to the drafting room, and the operations man to the field. Clearly, a major aspect is that of the need for mutual education and confidence. It is almost essential that there be people available who have some knowledge of both sides.

Some of these problem areas may not have been adequately studied - as evidenced, for example, from current Viet Nam operations. While inadequacies arise partly from the difficulty of predicting exactly where the next set of urgent problems will arise, they may involve even more importantly the lack of an adequate resource capability. In particular, the funding of applied research tends to attach itself to urgent problems, but at the last minute and on a short term basis only. For example, studies on the effects of hot and humid environments tend to be dropped as soon as the emergency ceases, thereby weakening seriously a capability which may then have to be reconstructed for the next occasion.

The above comments should not be taken to imply that present activities are completely inadequate. There is strong support throughout the country for basic research in many biomedical areas and there are also a number of Government laboratories both in and out of the armed forces whose

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work has been essentially in both obtaining and applying the research material. However, there are areas in which environmental problems have not been as carefully studied as they should be and the effort needed for effective communication among biologists, engineers and operations people is still unnecessarily great. In the study of injury related to machinery and unusual environmental stresses, much has been done and much will continue to be done. However, the rapid increase in the overall rate of technological development offers the possibility of straining our resources for meeting emergencies. For example, many biomedical problems which have arisen out of the discovery of nuclear fission and its technological applications are still very far from being solved after 20 years. Problems now becoming important in the areas of deep sea submergence will require a much more extensive effort than is now being made. How soon further problems of comparable difficulty will arise is unpredictable. Every effort should be made to avoid being caught short.

30 June 1967 D. E. GOLDMAN

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